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A REVUELTIAN (NORIAN) PHYTOSAUR FROM THE SONSELA MEMBER OF THE PETRIFIED FOREST FORMATION (CHINLE GROUP: UPPER TRIASSIC), PETRIFIED FOREST NATIONAL PARK, ARIZONA

ADRIAN P. HUNT, SPENCER G. LUCAS and ANDREW B. HECKERT

New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, NM 87104-1375

Abstract—The Sonsela Member of the Petrified Forest Formation (Upper Triassic) is widely exposed in northeastern Arizona and northwestern New Mexico. Fossil wood is common in the fluvial Sonsela, but the high energy depositional conditions appear to have destroyed all fossil bone except for small fragments. The first identifiable vertebrate fossil from channel-facies of this unit is an incomplete phytosaur skull preserved on a fallen block of sandstone on a cliff in the Rainbow Forest area of Petrified Forest National Park, Arizona. This cliff is "Flattops Sandstone 1," which we consider to represent the upper part of the Sonsela Member. The left side of the skull, lacking the anterior half of the rostrum, is preserved in lateral view. The specimen is uncollectable, but casts are preserved at Mesalands Dinosaur Museum, Petrified Forest National Park, and the New Mexico Museum of Natural History and Science.

The two most important morphological features of this specimen are: (1) the external nares are at approximately the same level as the skull deck; and (2) the posterior squamosal process in lateral view is narrow and not pendulous. This combination of features is diagnostic of the genus *Nicrosaurus*. The only other published account of *Nicrosaurus* in North America is *Nicrosaurus buceros* from the Chama basin of north-central New Mexico. The common *Nicrosaurus kapffi* and the rare *N. meyeri* occur in the Norian Stubensandstein of southwestern Germany.

This specimen is biochronologically significant as it demonstrates that the Sonsela is indeed Norian in age, as has been suggested previously. Paleobiogeographically, it is one of an increasing number of Late Triassic tetrapod taxa that were previously thought to be exclusively European in distribution (e.g., *Erpetosuchus, Aetosaurus, Stagonolepis*) that have now been identified in North America.

Keywords: phytosaur, Sonsela, Petrified Forest, Norian, Revueltian

INTRODUCTION

The Sonsela Member of the Petrified Forest Formation is widely exposed in northeastern Arizona and northwestern New Mexico (Lucas, 1993). The Sonsela is predominantly composed of sandstone and conglomerate and separates the underlying mudstone-dominated Blue Mesa Member from the overlying, mudstone-dominated Painted Desert Member. The Blue Mesa Member yields the type fauna of the Adamanian (latest Carnian) land-vertebrate faunachron (lvf) at Petrified Forest National Park (PEFO), and the Painted Desert Member contains a typical Revueltian (early-mid Norian) vertebrate fauna (Hunt and Lucas, 1995). The Sonsela itself contains few identifiable fossils. Indeed, the high-energy fluvial environment of deposition of the Sonsela resulted in almost total destruction of vertebrate remains. Here, we report on the first identifiable vertebrate fossil from the channel facies of the Sonsela Member (Fig 1: Hunt, 1995). Note that the specimens, including the aetosaur *Paratypothorax*, that Murry and Long (1989) attributed to the Sonsela Member actually derive from the Blue Mesa Member (Hunt and Lucas, 1992).

STRATIGRAPHY

The sandstone that contains the phytosaur skull (Figs. 1, 2A-B) has been mapped as the Flattops 1 sandstone of the Painted Desert Member by Billingsley (1985a, b). However, we consider this sandstone to be an equivalent of the upper Sonsela Member, even though it is separated by 25 m of mudstone from the Rainbow Forest sandstone that is generally considered to be part of the Sonsela (Fig. 1).

There has been some confusion historically as to which sandstone bodies within the PEFO pertain to the Sonsela. The "Rainbow Sandstone" of Cooley (1957), and as used by Akers et al. (1958), Cooley (1958, 1959), Billingsley (1985a,b), Ash (1987), Murry (1990), Lucas (1994, 1995), and Heckert (1997), is actually the basal part of the Sonsela Member (Deacon, 1990). The stratigraphically complex interval from the base of the Sonsela to the top of Flattops 1 has been various termed the "Camp Wash Zone" (Roadifer, 1966) or the "Rainbow-Sonsela complex" (Demko, 1994, 1995). Recent work by ABH and SGL clarifies these relationships. We recognize here that the "Rainbow Sandstone" comprises the basal Sonsela, as identified by Deacon (1990). We also note that the next higher persistent sandstone, which contains the phytosaur skull reported here, and forms the mesa top west of Jim Camp Wash, is traditionally assigned to Flattops 1 but may represent an upper bed of the Sonsela.

At its type section, the Sonsela consists of a tripartite sandstone-mudstone-sandstone division (Akers et al., 1958), with the medial mudstone portion strongly resembling the Blue Mesa Member in color and lithology. Therefore, we suggest that the beds variously identified as the Sonsela, Flattops 1, or top of the Camp Wash zone may in fact represent the upper sandstone body of the Sonsela. Points of detailed similarity include sandstone lithology, bedforms, and colors, both fresh and weathered. Conglomeratic facies are rarer in this interval than in the lower Sonsela at PEFO (Espegren, 1985; Deacon, 1990), a fact in accordance with our observations at PEFO and elsewhere (Heckert and Lucas, 1996; Heckert, 1997; Heckert and Lucas, this volume). We note also that the similarity of the mudstone interval between the two sand-

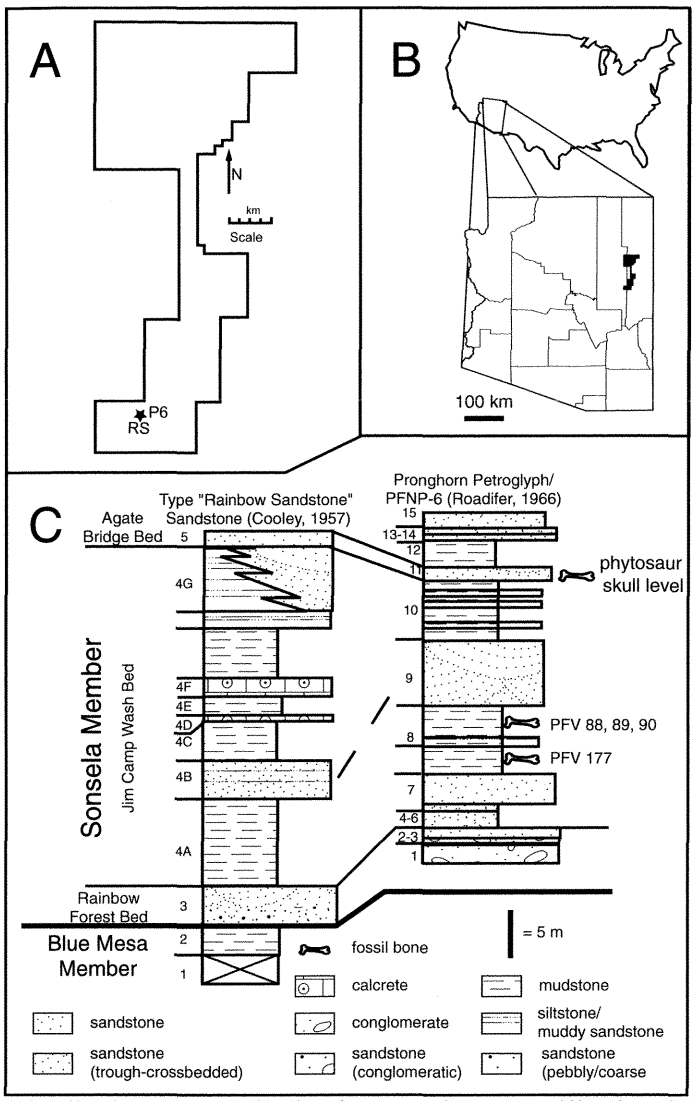

FIGURE 1. Location maps (A-B) and stratigraphic sections (C) at Sonsela phytosaur locality. On A "RF" marks the location of Cooley's (1957) Rainbow Forest measured section and P6 Roadifer's (1966) PFNP-6 section with additions from Heckert and Lucas (2002). Star marks the phytosaur locality. The localities on the measured section correspond to the following (from Evanoff, 1994; see also Parker, 2002): 90 = UCMP 84242; 89 = UCMP 84224 Bowman locality; 88 = UCMP V84220 Bat Cave; 87 = UCMP 84221 Jim Camp 1; 177 = UCMP V82232 Giant Logs.

stones to mudstones of the Blue Mesa Member, while a source of much of the confusion regarding the stratigraphic position of this interval, is consistent with medial mudstones at both the type section of the Sonsela Member and in numerous Sonsela sections in western New Mexico. Although this interval is stratigraphically thicker than most Sonsela mudstone intervals, the relatively thin sandstones below and above it result in a composite stratigraphic thickness of the Sonsela very similar to that seen in the Zuni Mountains in west-central New Mexico, particularly in the vicinity of Thoreau (Deacon, 1990; Heckert, 1997). Thus, in conclusion, we assign the phytosaur-bearing sandstone to the upper Sonsela Member.

The mudstone interval between the two sandstones of the Sonsela contains a number of fossil localities (Fig. 1). These localities yield fragmentary aetosaur scutes. Long and Murry (1995) referred this material to the aetosaur *Typothorax coccinarum*. We have not studied their material, but fossils observed in the field by ABH did pertain to *Typothorax*. We note here, however, that we have recently identified a second species of *Typothorax* and thus hesitate to assign these scutes to a particular species (Lucas et al., 2002).

TAPHONOMY

The phytosaur skull is preserved on a large, fallen block of sandstone on the edge of an unnamed mesa west of Jim Camp Wash (Fig. 2A). The sandstone is interpreted to represent a high energy fluvial environment on the basis of abundant intraformational conglomerates. The skull includes the left, lateral portion and is missing most of the rostrum and much of the ventral and posterior margins (Fig. 2C-D). The skull suffered considerable post-mortem damage, but the surface texture of the bone, where preserved, is good. Thus, the skull was broken, but not severely abraded. This indicates a period of severe mechanical damage, either by predators or more likely in the aquatic environment, followed by rapid burial. Lack of abrasion indicates short transport time in the stream. Extensive prospecting revealed no other bone fragments of any size in the sandstone outcrops of the immediate area. However, small, rounded fragments of petrified wood occur locally. Thus, the preservational factors that affected the skull were extremely unusual.

The skull is located on the top of a large boulder that has a massive structure that lacks obvious bedding planes and thus it would be extremely difficult to extract the specimen without power tools. The skull block is located down a boulder-strewn slope that makes accessibility a problem for large equipment. After discussions between APH and NPS personnel, it was decided that the environmental impact and expense of extricating the specimen was not justifiable and that it should be studied *in situ*.

DESCRIPTION OF SPECIMEN

The specimen is much of the left side of a phytosaur skull, posterior to the nasals (Fig. 2C-D). The skull fragment has a maximum preserved anteroposterior length of 410 mm and a maximum dorsoventral height of 205 mm.

The nasal is an elongate bone that terminates anteriorly at the suture with the premaxilla(?). The anterior margin of the external nares is preserved, but much of the dorsal surface has been removed The prefrontal, frontal and postfrontal are small bones that, respectively, enclose the orbit anteriorly, dorsally and posterodorsally. The orbit is subround, with a diameter of 58 mm.

Ventral to the orbit, the lachrymal and jugal form the strut that separates the antorbital fenestra from the inferior temporal fenestra. The antorbital fenestra had a rounded posterior margin and a maximum dorsoventral height of 95 mm, which is about 50% of the height of the skull at this point (185 mm). The anterior margin of the antorbital fenestra is not preserved, but it is still apparent that it must have extended anterior to the anterior margin of the external nares. The anterior and posterior projections of the jugal that should extend ventral to the antorbital fenestra and inferior temporal fenestra, respectively, are broken. The anterior projection was broken prior to burial, but the posterior one has been destroyed by Recent weathering.

The parietal extends posterior to the orbit, forming the anterodorsal margin of the inferior temporal fenestra. The fenestra is lacking its posteroventral margin and most of its ventral margin, but it was at least 152 mm in dorsoventral height and at least 90 mm in anteroposterior length. It was parallelogram-shaped, with the anterior and posterior margins angled posterodorsally. The squamosal forms the posteroventral margin of the skull and has a posterior process that is 40 mm long and 45 mm deep.

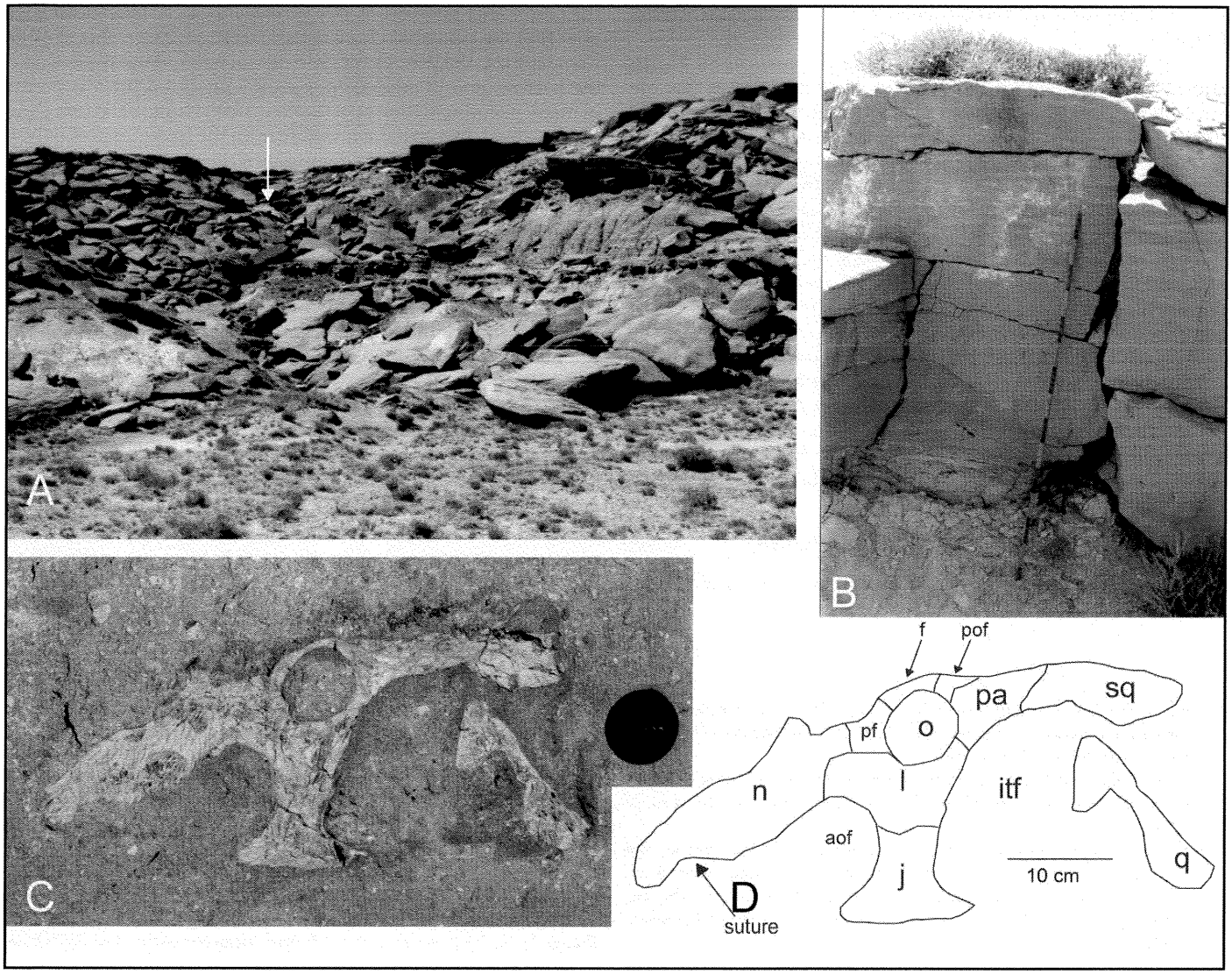

FIGURE 2. Occurrence and morphology of Sonsela phytosaur skull. **A**, Overview of locality with location of skull on fallen block indicated by arrow. **B**, Upper Sonsela Member sandstone (=Flattops 1 sandstone) from which the skull derives at location above fallen block (divisions on staff = 10 cm). **C**, Skull fragment of *Nicrosaurus* sp. in field. **D**, Interpretative drawing of the skull of *Nicrosaurus* sp. Abbreviations are: aof, antorbital fenestra, f, frontal, itf, inferior temporal fenestra, j, jugal, l, lachrymal, n, nasal, o, orbit, p, parietal, pf, prefrontal, pof, postfrontal, q, quadrate, s, squamosal.

TAXONOMY

The most diagnostic features of this skull are the co-occurrence of external nares at the level of the skull roof and posterior squamosal processes that are dorsoventrally compressed. This combination of characters is only found in the genus *Nicrosaurus* (Hunt, 1994). This genus currently contains the species *N. kapffi* (Meyer, 1860), *N. buceros* (Cope, 1881) *sensu* Hunt (1994) and *N. meyeri* Hungerbühler and Hunt (2000). The species-level diagnosis depends primarily on the morphology of the rostrum, and as this is incomplete in the PEFO specimen, it cannot be assigned unequivocably to a particular species. However, it is clear from the altirostral (*sensu* Hunt, 1994) morphology of the rostrum that it does not pertain to *Nicrosaurus meyeri*.

BIOCHRONOLOGICAL AND BIOGEOGRAPHICAL IMPLICATIONS

The genus *Nicrosaurus* is common in the Norian Stubensandstein of southwestern Germany (Benton, 1993; Hungerbühler and Hunt, 2000), but there is only one previous report of the genus in North America. Cope (1881) described and named, but did not illustrate, a skull (AMNH 2318) from New Mexico that is the first report of diagnostic phytosaurian material from western North America. This skull is from the upper part (Painted Desert Member equivalent) of the Petrified Forest Formation of the Chinle Group in Rio Arriba County, New Mexico (Hunt and Lucas, 1993; Lucas et al., this volume). Cope (1881) named this skull *Belodon buceros*. McGregor (1906, pl. 9) followed Cope's (1881) taxonomy but was the first to illustrate the specimen. Jaekel (1910) erected the genus *Metarhinus* for this species, but this name was preoccupied by a Paleogene mammal. Mehl (1915) placed the species in the genus *Lophoprosopus*. Huene (1915, fig. 11) illustrated this specimen and placed *buceros* in the genus *Phytosaurus*, whereas Mehl (1916) placed this species in his new genus *Machaeroprosopus*. Subsequently, Gregory (1962) placed the species in *Rutiodon* and Ballew (1989) in *Pseudopalatus*. Hunt and Lucas (1993) and Hunt (1994) considered *buceros* to be a valid species of *Nicrosaurus*. Recently ABH and Kate Zeigler and field parties from NMMNH have recovered new specimens of this taxon from the Petrified

Forest Formation of north-central New Mexico (Rio Arriba County).

It is clear that any occurrence of *Nicrosaurus* in North America is important for two reasons. First, it indicates that the strata that yielded the specimen are Revueltian (early-mid Norian) in age and correlative with the Stubensandstein. Second, it provides one of an increasing number of records of vertebrate taxa in North America that formerly were thought to be endemic to Europe, including the aetosaurs *Stagonolepis* (Murry and Long, 1989; Long and Murry, 1995) and *Aetosaurus* (Heckert and Lucas, 1998), the ornithosuchian *Erpetosuchus* (Olsen et al., 2000) and the sphenodontid *Clevosaurus* (Fraser, 1993). Late Carnian faunas are cosmopolitan in nature—witness the worldwide distribution of the phytosaur *Paleorhinus* (Hunt and Lucas, 1991) and the rhynchosaur *Hyperodapedon* (Langer and Schultz, 2000; Lucas et al., this volume), but Norian faunas are apparently less so. Thus, it is significant to find *Nicrosaurus* in North America in Norian strata that also contain (in New Mexico) the phytosaur *Pseudopalatus*, a taxon unknown in Europe. It seems likely that there is a paleoecological component to the biogeography of Norian phytosaurs.

ALTERNATE INTERPRETATIONS

The junior authors (SGL and ABH) are less certain about the taxonomic position of this phytosaur skull. Specifically, we note that the principal characteristic used to assign this skull to *Nicrosaurus* is the position of the external nares at the skull deck—the narrow, non-pendulous posterior squamosal process occurs in many pseudopalatine taxa (Ballew, 1989; Hunt, 1994; Long and Murry, 1995). In a specimen visible from the lateral aspect only, it is essentially impossible to determine if the nares are in fact at the level of the skull deck naturally or as a result of post-mortem crushing. Consequently, we interpret this skull as that of a pseudo-palatine phytosaur, either *Pseudopalatus* or *Nicrosaurus*. Although this renders the paleobiographic conclusions regarding *Nicrosaurus* more problematic, we note that both *Pseudopalatus* and *Nicrosaurus* are restricted to strata of Revueltian (early-mid Norian) age, and thus that this skull supports a Revueltian age for the Sonsela Member regardless of whether it is *Pseudopalatus* or *Nicrosaurus*.

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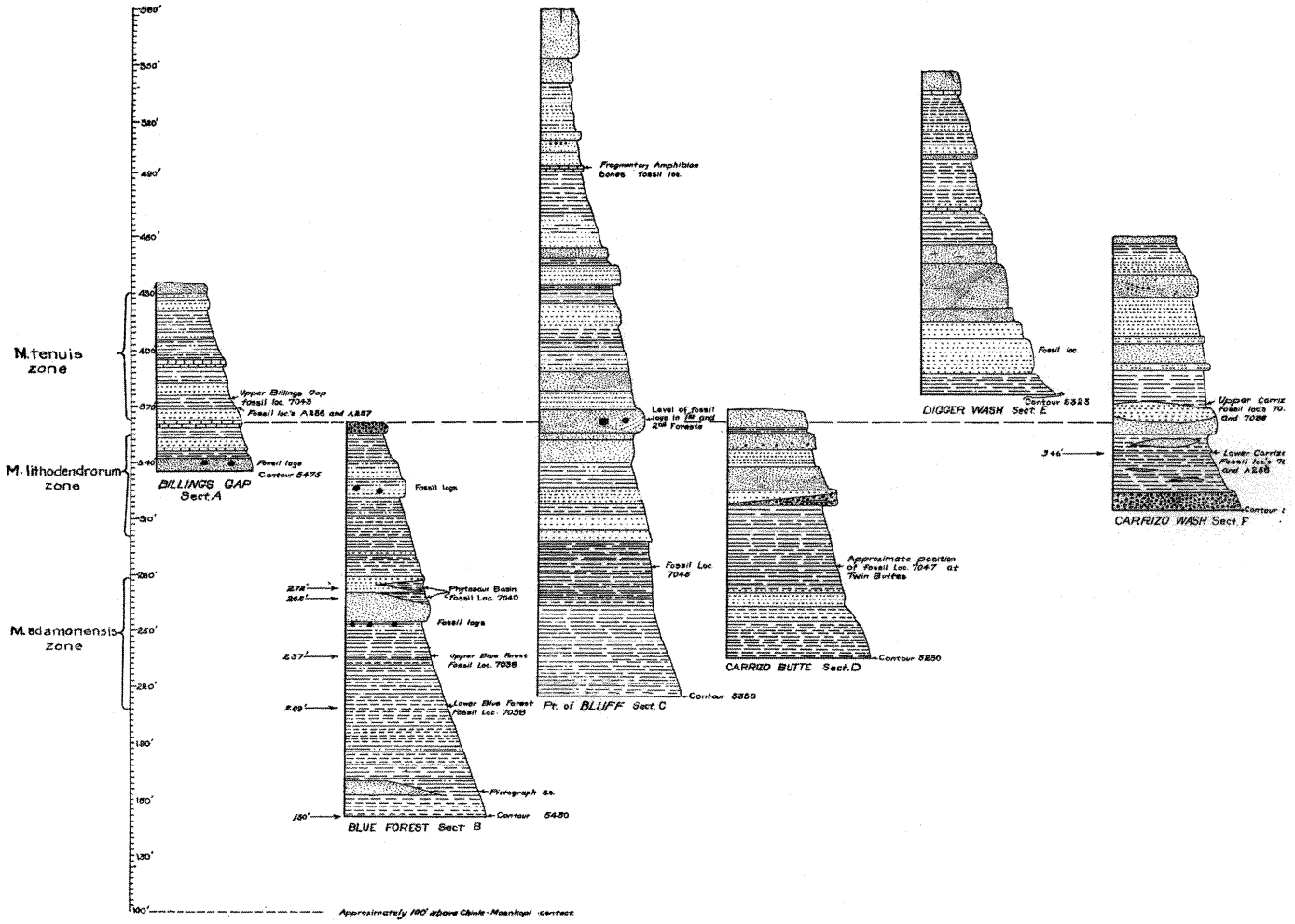

Stratigraphic sections taken at various points in the Lower Chinle near Adamana, Arizona (cf. map B). Columns indicate total available hight of exposure at each station. Base levels of sections from United States Geological Survey Petrified Forest and Fort Defiance quadrangles (from Camp, 1930, fig. 1, p. 16).